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APPROACH TO NATION-WIDE NETWORK SIMULATION MAKING VIRTUAL REALITY FOR TELECOMMUNICATION NETWORK MANAGEMENT

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ABSTRACT

Intelligent Decision Support System (IDSS) is being developed to improve support for network operators managing and administrating nation-wide telecommunication networks. This paper describes the concept of IDSS, and the architecture of its simulator. The network simulation is IDSS's key function, which establish virtual reality of nation-wide telecommunication networks. High-speed simulation is necessary to establish the virtual reality. In this paper, modeling for high-speed simulation with parallel processing is also described.

1 INTRODUCTION

The development of an information-intensive society has resulted in telecommunication networks becoming larger and complicated. Each year sees new services and the appearance of new common carriers. Due to the wide range of services and their usage patterns, it is difficult to forecast service demand and their traffic patterns. Under such circumstances, network providers should provide a high-survivability network keeping GOS (Grade Of Service). Telecommunication network control capabilities are being improved in order to effectively handle unplanned/ unforeseen traffic and to improve network survivability. These improvements are achieved by advanced control techniques such as routing control (Yamamoto et al. 1991), congestion control and network-facility assignment control (Yamada and Inoue 1991).

Network operators/network management & administration centers require powerful decision support capabilities to make efficient use of the advanced control capabilities and to manage telecommunication networks. An Intelligent Decision Support System (IDSS) (Inoue, Ito and Yamamoto 1992) is being developed to achieve these requirements.

A network operator might meet a situation of which he has no experience. In such a case, he would like to test different control actions before the actions carry out. However, different control actions cannot be tested on an actual network. For the purpose of supporting these network management operations, a new environment for network management is proposed in this paper. This environment is termed "virtual reality" in this paper. In the virtual reality world, he can carry out the actions as if he operated an actual system. And then, on the basis of the virtual experience, he can carry out the most appropriate action in the actual network.

IDSS consists of several modules such as a network simulation function, a performance evaluation/analysis function and so on. One of objectives of IDSS is to provide the virtual reality environment. An analytical method is not enough way to make the environment. An actual telecommunication network has an enormous number of factors concerning network structure, traffic patterns, and control parameters. A realistic-scale simulation of a nation-wide telecommunication network has been difficult because of the limitation of computer power (processing speed, memory capacity, etc.) and computer running-costs. And besides, it is difficult to introduce a super computer system in each network management & administration center in order to use such a new decision support system. Therefore, both high-speed and low-cost simulation are required in order to make the virtual reality.

Parallel processing techniques are effective methods to achieve these requirements. Network-facility dependent modeling in telecommunication networks has been developed for parallel processing. However, there are some difficulties on network simulation. One is that access to the same data occurs very frequently. For example, there is a possibility that each link between switching nodes is used as an alternate route between any node-pair in a network with dynamic routing. Therefore, such a modeling that each switching function is simulated in each CPU is not the best way to achieve high-speed simulation under realistic-scale network conditions. A new modeling method suitable for nation-wide network simulation is required to make good use of parallel processing capabilities.

This paper presents the new concept of the virtual reality for telecommunication network management. It introduces the system architecture of the network simulator to make the virtual reality environment and its parallel processing techniques.

2 OVERVIEW OF IDSS

2.1 Background

The network control methods are classified into three control functions, i.e. routing control, congestion control (Mase and Yamamoto 1990), and network facility assignment control (Yamada and Inoue 1991). The main objectives of network control against traffic fluctuations or network failures are to prevent the GOS from seriously deteriorating and to minimize the resulting propagation of the congestion.

Each control method needs to satisfy two objectives: One is to execute control actions instantaneously using preplanned action patterns built into each network element such as an exchange and a digital cross-connect switch (DCS). And the other is to achieve optimal control based on network-wide information by using centralized control methods. The efficiency of hybrid control strategies using multiple action processes and the necessity of total control using multiple control methods have been shown (Inoue et al.1991).

2.2 Concept of IDSS

To achieve this advanced network control, the network operators/network control centers must have powerful decision support capabilities. The objectives of an Intelligent Decision Support System for advanced network control (IDSS) (Inoue, Ito and Yamamoto 1992), which is being developed in NTT Labs, are as follows:

-To evaluate the performance of each control scenario under conditions similar to those of real networks - that is, with realistic network scale, network structure, traffic volume, control systems, etc.

-To evaluate the effects of multiple network controls combining two or three of the main controls, several routing control, congestion control and network facility assignment control.

These capabilities allow the most appropriate control scenario for a specific network condition to be chosen from among many alternatives.

IDSS can support the following functions:
1) Preparing pre-planned action patterns ,
2) Making action plans according to network conditions,
3) Training network operators to appropriately deal with various situations.

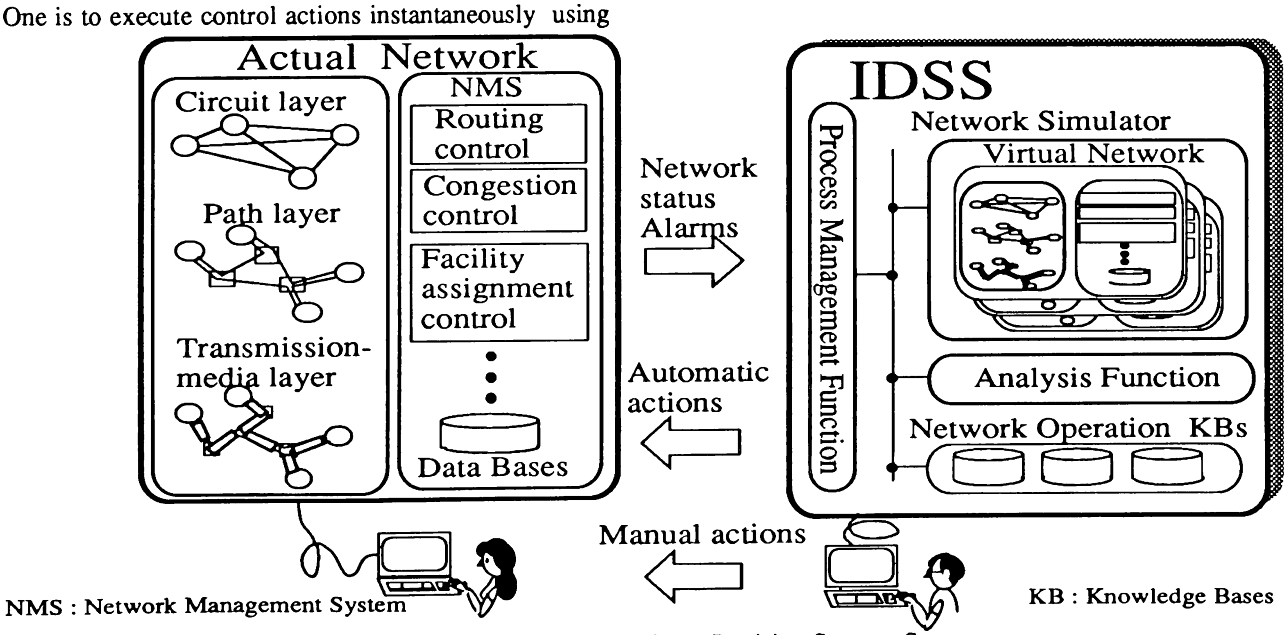

Figure 1: Architecture of Intelligent Decision Support System

2.3 Virtual Reality in IDSS

IDSS consists of a simulation module for telecommunication networks, a network performance evaluation/analysis module, network-operation knowledge-bases (KBs), and a process management module (Inoue, Ito and Yamamoto 1992). The system architecture of IDSS is shown in Figure 1.

Network simulation is the key function to realize the virtual reality of telecommunication networks.

There are three simulation modules corresponding to the three layers of a telecommunication network: (1) a circuit-layer network simulation module which simulates call connection processes, (2) a path-layer network simulation module which simulates conditions of circuit assignments in the path-layer network, (3) a transmission-media-layer network simulation module which simulates conditions of path assignments in the transmission-media-layer network. Each module can simulate - in virtual networks on computer systems, that is, in the virtual reality world - such various conditions as the current condition, future conditions, and an ideal condition. A telecommunication network model in the virtual reality world is called "virtual network" in this paper. A virtual network includes network management systems such as routing control center, and related databases.

An operator, that is a decision maker, orders various control actions on these virtual networks, and then gets the results of performance evaluation and network conditions as shown in Figure 2. The concept of this network simulator is similar to that of a flight simulator.

The first target is to develop the circuit-layer network simulation module. The simulator and its techniques are described below on the circuit-layer network.

3 NETWORK SIMULATOR IN IDSS

3.1 Requirements for Network Simulator

This network simulator as a practical tool should satisfy the following conditions.

(1) Realistic Network Conditions
A network condition is defined by the network structure (number of nodes, number of links between nodes, topology), number of trunks in each link, the traffic volume, control parameters, and so on.
The scales of realistic transit network in Japanese are shown as below.

- Number of nodes : $O(10^2)$
- Number of trunks : $O(10^5)$
- Traffic volume : $O(10^5)$ erl

(2) High-speed Simulation
The goal is that the required CPU time decrease less than the simulation time using a mini-computer with parallel processing.

(3) Flexibility with Simulation Conditions
The simulator must be able to handle many parameters for network models, traffic conditions, and control actions. The next section describes the architecture of the network simulator that satisfies these requirements.

3.2 Architecture of Network Simulator

The architecture of the network simulator in IDSS is shown in Figure 3. The simulation unit consists of a simulation controller, a scenario, data sets, a network management center, a network observation center, and a network simulation engine.

The network model, the traffic conditions and various control parameters are defined in this scenario. The simulation controller sets the attributes and the parameters of network facilities such as switching nodes and centers. There are two processes for a network management & observation center and for a network simulation that simulates call-level procedure. The simulation controller controls the processes based on the scenario.

The roles of the system controller are to control simula-

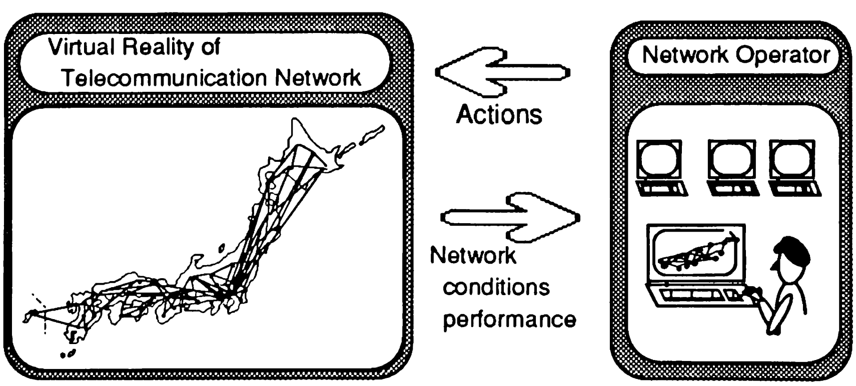

Figure 2: Concept of Virtual Reality of Telecommunication Network

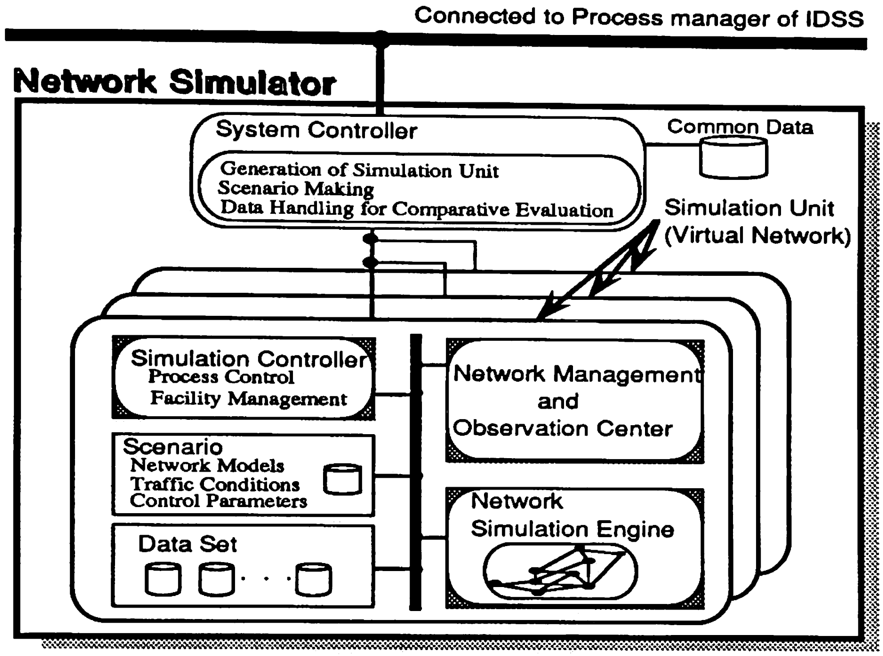

Figure 3: Architecture of Network Simulator

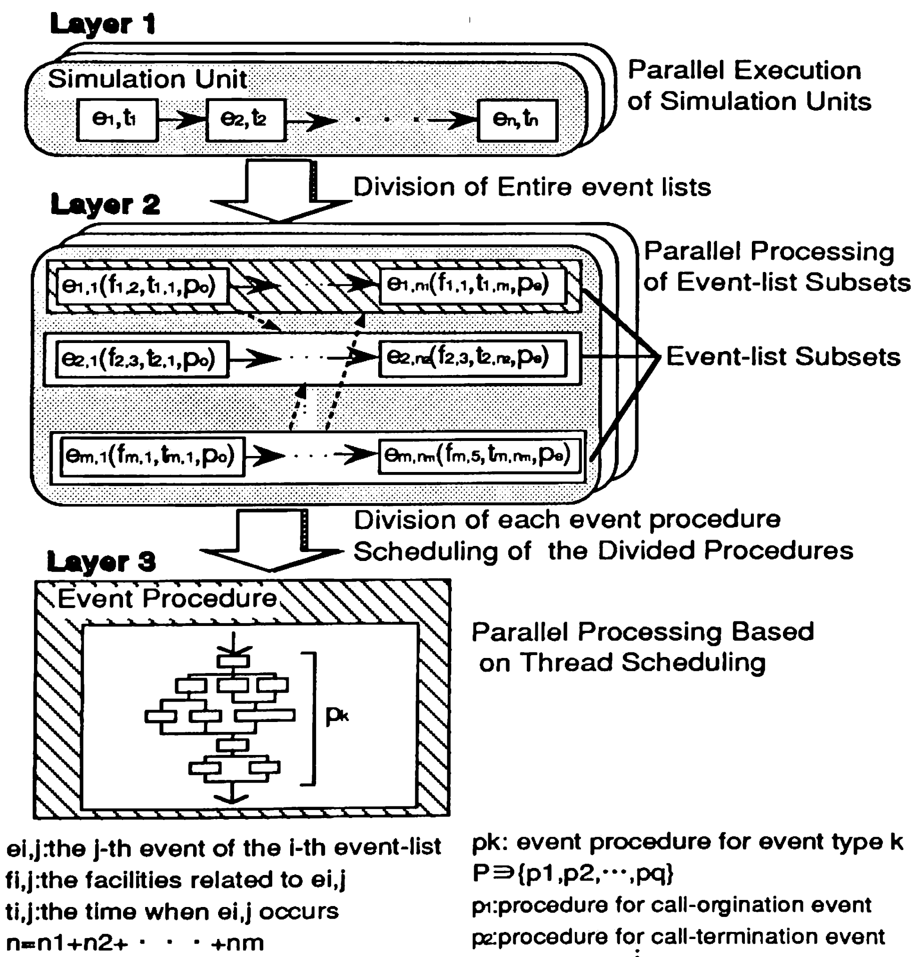

Figure 4: Hierarchical Modeling for Parallel Processing

tion units, to manage graphical interfaces, and to maintain and update various types of data.

A simulation unit is a virtual network. The system controller can generate multiple simulation units to evaluate various actions at the same time. A user can handle any unit at any time through the system controller.

In other words, a user can make various virtual networks according to the purpose, and can order various actions on these virtual networks as a network manager or a network operator.

The next section describes the technical points of high speed simulation using parallel processing techniques.

4 MODELING AND ITS PARALLEL PROCESSING TECHNIQUES

The simulation procedure is divided into three layers to apply parallel processing techniques to network simulation. A model and a purpose of each layer, which is shown in Figure 4, are described in the following sections.

4.1 Parallel Execution of Simulation Units

An operator rarely finds the best action immediately after the occurrence of some trouble - failures of network facilities, unpredictable traffic variations, etc. Generally, there are several action patterns to settle the trouble. In order to evaluate some action patterns quickly, multiple simulations should be executed in parallel independently. Each simulation has its own scenario with a different action pattern.

A virtual network, i.e. a simulation unit, is generated for each scenario by the system controller (See Figure 3). An execution module of each simulation unit is generated by copying and assembling original files according to the purpose. If the operator wants to evaluate several different action patterns under the same condition, each simulation is started from one condition copied from the common data of original files. The system controller can order a different CPU to execute each simulation unit.

If a parallel computer has n CPUs and the number of scenarios is equal or less than n, the required computer run-time for comparative evaluation can be decreased to $1/n$. It is easy to implement this mechanism of layer 1 by using multi-CPU computer.

4.2 Parallel Processing of Event-list Subsets

A simulation procedure executed in a simulation unit is expressed by an event-list as shown in Figure 4. An event e is defined by event procedure p (for example, call-origination, call-termination), facilities related with the event, f, and the time at which the event occurs, t.

The current version of IDSS's simulator executes this event-list sequentially by the time-true simulation mechanism (McAffer 1990). The aim of layer 2 is to achieve high-speed simulation by dividing the event-list into several subsets.

Each subset is executed on a different CPU. This mechanism is a parallel simulation (Inoue et al. 1989). Parallel simulation methods (Fujimoto 1990) are classified into two categories. One is a conservative simulation method, and the other is an optimistic simulation method. In a conservative simulation method, an event that is scheduled so as to guarantee no causality error should be executed on each CPU. On the other hand, an optimistic simulation is a method without guarantee of no causality error. When a causality error is detected under simulation, the error is recovered using a rollback mechanism.

In a telecommunication network with dynamic routing, an originating-call might access any node and any link. This implies that almost all the events may access the same data. Therefore, the following trade-off should be considered: between the required time to schedule events so as to guarantee no causality error and the required time to detect and recover causality errors. And how to divide a simulation unit into subsets should be determined to minimize the total CPU run-time required for a simulation unit.

A subset of an event-list is made by dividing network facilities into several facility-sets. Each subset consists of only the events related with the facilities in the same facility-set. For the purpose of minimizing the possibility of causality-error occurrence, each facility set is determined based on the traffic volume, the network structure, and the amount of managed facilities.

In layer 2, event-list subsets made by the above-mentioned procedure are executed using an optimistic simulation method.

4.3 Parallel Processing Based on Thread Scheduling

The aim of Layer 3 is to apply parallel processing to the event-procedure level. The simulator has minimum-searching of the next event, searching and updating for available trunks, and other procedures of data manipulating in an event-procedure. Some of them don't need to run sequentially. Because flows of all event procedures are able to be identified before running, each event-procedure can be analyzed to find parts for which parallel processing is applicable.

When scheduling the parts, the data-dependency must be examined. In layer 3, the thread scheduling is carried out so as to guarantee data-dependency processed correctly. Therefore, each event-procedure is carried out using pre-scheduling by analysing data-dependency between each part.

5 CONCLUSION

This paper presented the concept of the virtual reality as a new environment for network management and the key technique, the nation-wide network simulator. The goal of this simulator is to make the virtual reality environment of nation-wide telecommunication networks. By using this simulator, each control scenario alternative can be simulated under various realistic network conditions. This environment is called the virtual reality. Application examples are as follows:

- To make the best action through the repeated experiences under the same network conditions.
- To know the future network conditions by putting the time forward.
- To analyze the reason of the operational failure by tracing the executed actions.

In IDSS, operators can determine an appropriate action scenario on the basis of both evaluation results obtained from the network simulator and empirical knowledge stored in the network operation KBs.

The objective of the virtual networks is to make and verify actions not only for network control and management, but also for network administration and engineering. Examples are to make and verify trunk-increase/decrease actions, and to make and verify dimensioning plans.

A modeling method and its parallel processing techniques suitable for telecommunication network simulator were proposed to achieve both high-speed and low-cost simulation in this paper. IDSS is under development. It must be a powerful decision support system in near future.

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